AGRICULTURAL INTENSIFICATION IN WEST AFRICA: INSIGHTS FROM SASAKAWA GLOBAL 2000'S EXPERIENCE

by

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ABSTRACT

High population growth rates and increasing urbanization present a challenge to policy makers in West Africa to motivate and assist farmers in using new technologies to improve productivity and increase agricultural production needed to address structural food deficits. This paper discusses efforts by Sasakawa Global 2000 to work with farmers and Ministries of Agriculture to test and promote adoption of appropriate, profitable technologies that increase yields and improve soil fertility. In Ghana and Benin, this approach resulted in a 300% yield improvement in farmers' experimental plots of maize and sorghum, in addition to serving as a successful example to the national extension system and a network of rural savings associations. More recent efforts to introduce new technologies to farmers in semi-arid areas of Burkina Faso and Mali are confronted by a more fragile ecosystem: nutrient poor, badly drained soils; and insufficient and unevenly spaced rainfall. When combined with highly variable producer prices, weak marketing and social infrastructure and less responsive millet varieties, farmers have adopted risk-averse strategies that seek to assure household food security while constraining innovation. In Mali, SG's strategy includes efforts to combat wind and water erosion and use natural phosphates and legumes. While partial budget analyses reveal a high marginal rate of return for Apron treated seed varieties without any complementary inputs (237%), returns on the use of mineral fertilizers have to date proven inconclusive. The varying degree of adoption of these packages by farmers raises the question of whether future efforts must more thoroughly consider the effect of agro-socioeconomic factors that affect farmer motives, particularly the need to minimize yield variability in the more risky environment of the Sahel.

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West Africa is experiencing population growth rates unprecedented in its history. From 45 million people in 1930, total population in West Africa has grown to 220 million in 1994. At current growth rates, population is expected to double by 2020 (WALTPS). Faced with this strong demographic pressure, producing enough food to assure the food security of a growing population presents a major challenge to West African governments. The introduction and adoption of new technologies needed to intensify agricultural production appears indispensable if countries are to meet this objective.

What are the different constraints and potential outlook for technological innovation in the West African food sector? Is it feasible to transform the agricultural sector in the risky regions of the Sahel; and if so, under what conditions? This agricultural challenge has become a priority of the Sahel 21 forum, initiated in 1995 by CILSS and the Club du Sahel/OECD to create a Sahelian vision of the future of the region to help guide development efforts.

The first section of this article discusses the critical issues linked to the intensification and transformation of West African agriculture. The second section examines the experiences of the non-governmental organization Sasakawa Global 2000 (SG 2000) in Benin and Ghana in increasing agricultural productivity in West Africa through the introduction of new technology and the easing of certain constraints facing farmers (notably, information and low purchasing power). The third section presents preliminary results from SG 2000's Malian program where input intensive technologies are being introduced in high risk production environments using farmer-managed demonstration plots. In addition to showing the agro-socioeconomic diversity of West Africa, the presentation of the Malian program highlights the challenges of transforming the agricultural sector in a high risk environment.

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1. WHAT IS AT STAKE: INTENSIFYING AGRICULTURAL PRODUCTION

1.1 The Impact of Agricultural Transformation on Development in West Africa

There is no question that West African countries must develop their agricultural sectors in order to improve the food security of their populations. Several reasons justify the central importance of food security to development in the region:

- Domestic food production employs a large percentage of the population, albeit at a low level of productivity. Capital and organizational constraints have created structural rigidities that impede movement of the population to other sectors.

- In Sub-Saharan Africa, improved agricultural technology can lead to a substantial increase in national income.

- The alarming projections of food needs in the year 2010 highlight the need for structural changes to agriculture.

Despite the different assumptions used in studies by the World Bank, IFPRI and the FAO to forecast food needs in Sub-Saharan Africa, they converge on one point: the future is worrisome because local food supplies are not expected to meet growing demand. The results presented in Table 1 show that the food deficit in Sub-Saharan Africa will increase by a factor of 2 to 4 between 1990 and 2010.

Table 1. Projected Cereal Production and Import Needs for Sub-Saharan Africa

Forecasts 1989 - 2010	FAO	IFPRI	World Bank
Estimated production (million tons)	110	86	83
Estimated annual growth rate (%)	3.5	2.3	2.1
Estimated demand (million tons)	129	118	96
Estimated annual growth rate (%)	3.5	3	2
Estimated imports needed (million tons)	19	32	14

Source: Brun 1996, p.14.
Note: Actual growth rates from 1989-91 were 3.4% for production, 3.1% for demand, and 8% for imports.

Forty percent of the West African population lives currently in urban areas. By 2020, this is expected to increase to 60%. The West Africa Long Term Perspective Study (WALTPS), conducted in 19 countries in West Africa, argues that the growing importance of large urban areas and increasing urban demand offer many commercial opportunities to farmers and consequently, the incentives to intensify agricultural production (Snrech and de Lattre 1994). Supply response may prove difficult to the extent that a persistent and vicious circle of poverty in rural areas prevents most farmers from saving money to invest in agriculture. These problems lead one to question how the constraints can be eased so as to promote intensification of agricultural production.

1.2 Theoretical Links Between Intensification and Agricultural Transformation

Expanding food production requires fertile soils. Weight and Kelly (1998) identify four primary soil types in Sub-Saharan Africa, each with different implications for restoring soil fertility:

- Top-quality land containing high levels of organic matter and water retention capacity; this type represents approximately 10% of cultivable land in Africa.;

- High-potential land (7%) containing a good level of organic matter but exhibiting certain physical limitations. While vulnerable to a reduction in organic matter and fertility when few inputs are used, this land maintains good recapitalization potential.

- Low to medium potential land (28%), which is very vulnerable to a decline in organic matter and fertility when few inputs are applied. This land could be recapitalized if appropriate techniques and practices adapted to these conditions are used.

- Marginally sustainable land with soils characterized by limited organic matter and water retention capacity. This category, representing 57% of land in Africa, is in large part not cultivable, especially in the Sahara desert. Arable zones are located essentially in the Sahelian zone on the fringe of the desert and have severe water and nutrient deficiencies. Although recapitalizing this type of land is not completely understood, there are indications that it is possible.

Long fallow periods have traditionally been used to restore soil quality and yield levels in Sub-Saharan Africa. In recent years, demographic pressure on land has shortened the number of years fields are kept fallow to the point that fallowing alone is insufficient to maintain soil fertility. In this context, what are alternative techniques needed to recapitalize and improve soils and thus increase production? What are the socioeconomic conditions required to facilitate this agricultural transformation?

Two different points of view exist on the best way to increase production in sub-Saharan Africa:

- Certain authors believe that the African continent does not have any particularities distinguishing it from the rest of the developing world (Asia and Latin America). Agricultural development is hindered only by a minimal use of new technologies, notably improved seed varieties and fertilizers. Researchers espousing this viewpoint (e.g., Lipton 1989; Smith et al. 1994) believe that there is good agricultural potential in Africa if a sufficient number of farmers use new technology.

- Another group believes that insofar as producers in Sub-Saharan Africa have enormous financial constraints and large numbers farm exclusively in risky, rain-fed systems, new technologies should not require lots of externally supplied inputs. Instead, technological innovation should be based on increasing productivity, and conserving and preserving existing natural resources already available to farmers (Cf. Harrison 1990; Spencer 1991 and 1995; Lynam and Blackie 1991).

Byerlee and Heisey summarize the debate by asking whether to promote “input-intensive or input-efficient varieties.”

Rather than arguing the pros and cons of the opposing theoretical viewpoints, (cf. Reardon 1998, p. 444), we examine the experiences of Sasakawa Global 2000 in West Africa, in an attempt to draw some lessons about agricultural transformation in a risky environment like the Sahel. As a prelude to this discussion, it is important to highlight the necessity of taking both socioeconomic and agro-ecological factors into account during the agricultural transformation process in West Africa.

Farmers can only use new technology in a sustainable manner if it increases profits (Binswanger 1986). The opportunity to earn profits is the primary motivation for adopting new technologies, whether they are valued through the market or in home consumption. The existence of a minimum set of institutional conditions both upstream (access to inputs) and downstream (markets capable of absorbing increased production resulting from technological innovation) are critical to the continued use of new technologies (Coulibaly 1996). The explosion in micro-finance initiatives in recent years indicates an increasing realization on the part of development workers that financial support to farmers is indispensable -- either in the form of returns earned on savings or credit received -- to generating the economic surplus needed to reduce poverty in rural areas.

Recognition of the importance of the agro-ecological and socio-economic aspects of agricultural transformation underlie SG 2000's efforts to propose new technology packages to farmers and improve access to credit through the creation of rural savings and loan associations and cooperatives in West Africa.

2. SG 2000'S EXPERIENCES IN HUMID AND SUB-HUMID ZONES OF WEST AFRICA

Following numerous famines in Africa in the 1980s, and with an interest in addressing the structural causes of food insecurity in Sub-Saharan Africa, the Sasakawa Association for Africa and Global 2000 of the Carter Center formed a partnership to create a non-governmental organization, Sasakawa Global 2000, to undertake agricultural projects in Africa.[1] SG 2000 seeks to increase food production by transferring proven, new technology to small farmers. Beginning in Ghana and the Sudan in 1986, SG 2000 carries out projects in approximately 12 countries in Sub-Saharan Africa. Since 1996, SG 2000 has been working in Mali and Burkina Faso. Although new aspects have been incorporated into the Sahelian program, the main elements of the SG 2000 approach remain the same:

- Close collaboration with the Ministry of Agriculture;
- Direct farmer participation in technology transfer;
- Promotion of agricultural intensification with appropriate, financially viable technology.

2.1 The Underlying Principles of SG 2000's Actions in West Africa

2.1.1 Close Collaboration with the Ministry of Agriculture

Rather than creating a parallel structure, SG 2000 works in close collaboration with Ministries of Agriculture. Extension programs are jointly developed and ministry personnel serve as field agents. SG 2000 works exclusively with food crops, restoring and maintaining soil fertility and developing functioning cooperatives. It collaborates with research institutes and other development organizations in order to support the extension program.

2.1.2 Direct Farmer Participation in Technology Transfer

Extension efforts center around the production test plot (PTP): a half-hectare parcel owned or managed by a participant farmer who agrees to test the new technology on his/her own field. Testing on farmers' fields allows producers to compare his/her current practices to those recommended. SG 2000 views farmers' direct involvement as an irreplaceable part of the change process. Dr. S.A. Knapp, one of the founders of extension services in the United States, summarizes a fundamental tenet of extension strategy: "What a farmer hears, he rarely believes; what he sees in his neighbor's field, he doubts; but what he does himself, he cannot deny ."

2.1.3 Promote Agricultural Intensification with Appropriate, Financially Viable Technology

Different technology packages are recommended (Galiba 1989, 1994). Farmers receive input credit to allow them to accurately evaluate the innovation and temper the risk associated with each new approach. The investment made with the input credit represents in most cases a source of capital for future activities.

[1] SG 2000 was created and is financed primarily by Mr. Sasakawa Ryoïchi, President of the Sasakawa Foundation (presently called the Nippon Foundation).

As farmers are faced with soil degradation and negative mineral balances (Smaling 1993; Gakou et al. 1995), SG 2000 stresses the use of organic and mineral fertilizer. Intensification practices are recommended (Brown and Addad 1994) as well as the use of local resources such as natural phosphate (Bationo et al. 1997). The use of complex fertilizers (i.e., NPK) and urea was improved by the introduction of bulk blend fertilizers specific to cereals. In combination with improved varieties and cropping practices, SG 2000 is able to offer a menu of technological package options to farmers (Galiba et al. 1999).

2.2 SG 2000's Activities in Ghana

From 1986 to 1990, more than 100,000 production test plots of maize and sorghum were planted in ten regions in Ghana. Test yields averaged 2 t/ha for sorghum and 3.5 t/ha for maize for the 6,260 plots of sorghum and 3,368 plots of maize (Yudelman et al. 1991). These yields were 300% higher in plots using the recommended technologies relative to those based on traditional practices (Martinez et al. 1990). The 1991 evaluation of the Ghana program by an external team (Yudelman, Coulter, Goffin, McCure and Ocloo) estimated that SG 2000's efforts contributed to an increase in total maize production by 30,000 - 40,000 tons. The availability of new technology options has allowed thousands of small farmers to improve their food crop production. In recommending the continued use of demonstration plots, the evaluation suggested that future program objectives be more clearly defined and the management improved. A study on the dissemination of maize technology in Ghana showed that the well-conceived demonstration program, farmer and community involvement and focus on credit and input supply constraints have served as an example to the national extension service.

2.3 SG 2000 in Benin

SG 2000 began its activities in Benin in 1989, hoping to build on the lessons from Ghana as well as improve the program in the areas of cooperatives and credit. Production test plots included cassava in addition to maize and sorghum. Farmers were allowed to create rural savings and loan associations in order to continue the credit and extension program. More than 20,000 production test plots have been established in Benin on which new technologies were introduced. Mucuna was planted with maize to combat dog grass and to improve organic matter (Galiba et al. 1998). These efforts resulted in PTP maize yields that averaged 3.5 t/ha, representing an increase of 328% (Galiba 1994). Partial budget analysis estimated the marginal rate of return at 169% (Table 2).

Table 2. Partial budget analysis of Maize PTP in Benin

	Control plots	Production test plots
Average Grain Production (kg/ha)	1,000	3,000
Variable Costs		
Seeds (FCFA/ha)		2,600
Fertilizer		
- *NPK (FCFA/ha)*		18,000
- *Urea (FCFA/ha)*		9,000
Additional Labor		
- *Person-days/ha*		20
- *Person-days/ha@ 750 FCFA/ha*		15,000
Total Variable Costs (FCFA/ha)		**44,600**
Gross income (FCFA/ha)	**60,000**	**180,000**
Marginal net benefit (FCFA/ha)		**75,400**
Marginal rate of return		**169**

Source: Table based on Galiba 1994.

Notes: Seed cost: 20 kg/ha at the price of 130 FCFA/kg of improved seed
Price of NPK and Urea: 90 FCFA/kg
Price of maize grain: 60 FCFA/kg

Although the adoption of mucuna by thousands of farmers is a positive development (Versteeg et al. 1998; Houndekon et al. 1998), the principal innovation of the SG 2000 program in Benin is in the area of input supply and credit. Today, there exists a federated network of 125 rural savings and loan associations representing 22,746 members. In 1998, total deposits reached 1,684,605,851 FCFA (Von Pischke 1999). From 1996 to 1998, more than 2,000 tons of fertilizer at a total cost of 347 million CFA francs were managed by the rural savings and loans and distributed to members. Farmers who had graduated from the SG 2000 program were thus able to continue their application of the technology recommendations on 3,705 hectares of maize and 2,908 hectares of rice, obtaining yields of 2,7 t/ha for maize and 2.9 t/ha for lowland rice (Galiba and Glehouenou 1998). The creation of a network of rural savings and loans (FENACREP) allowed thousands of farmers to continue using the new technologies, and thus be better equipped to assure their own sustainable development.

3. ADDRESSING THE PRINCIPAL CONSTRAINTS TO AGRICULTURAL INTENSIFICATION IN THE SAHEL

The description of the SG 2000 programs in Benin and Ghana presented in Section 2 reflects the standard approach used by SG 2000 to date in West Africa. This approach, however, may need to be modified as SG 2000 undertakes the task of promoting intensification in the Sahelian environment. In this region, the agro-socio-economic situation differs substantially from that in the coastal countries of West Africa. For example, yield potential for millet, one of the principal Sahelian cereal crops, is much lower in Mali (300-700 kg/ha with traditional technologies and 800-1,200 kg/ha with improved technologies) than the yield potential for maize, the principal cereal crop in Benin (1000 kg/ha with tradition technologies and 3000 kg/ha with improved technologies). Furthermore, the yield variability across zones and years tends to be greater in the Sahel than in areas with more regular rainfall.

In the first part of Section 3 we review the key factors that render Sahelian agricultural production and intensification more risk-prone than production and intensification in other parts of sub-Saharan Africa (SSA) where SG 2000 has worked in the past. We then illustrate these general points by referring to progress made and problems encountered in the SG 2000 programs now underway in the Sahel (Mali and Burkina Faso). The section ends with a discussion of a research program now being launched to better understand the impact of risk on Sahelian farmers' decisions to participate in the SG 2000 program and their willingness/ability to continue using the new technologies on their own.

3.1. A High-Risk Environment

3.1.1. The Principal Constraints

Fragile Soils. A large part of the soils in the Sahel fall into the category of 'fragile' or 'marginal' soils, easily subject to both wind and water erosion. They tend to drain poorly and have low levels of organic matter. In many cases, deep plowing or the use of heavy equipment can rapidly lead to further deterioration of soil quality. Hence, there is a need to develop technologies that are well-adapted to the soil conditions that exist in the Sahel.

Inadequate Rainfall. Rainfall in the Sahel tends to be low, less than 700 mm/year (Idachaba 1993, p.55). It is poorly distributed throughout the rainy season: frequent periods of more than 10 days without rainfall. Rainy seasons are also very short: 90-100 days. Few cereals can grow under these difficult conditions, hence the less productive but more drought-resistant cereals such as millet and sorghum predominate. Further complicating the picture is the high variability in rainfall across time and space, making it difficult for Sahelian farmers to predict what the season will bring and what impact it will have on yields.

Excessive Pressure on the Natural Resource Base. Increasing desertification is a major problem in the Sahel.[2] It is a result of demographic pressure, coupled with a failure to control practices that deplete the natural resource base (e.g., cutting down forests without adequate replanting, limited adoption of anti-erosion measures). One of the consequences of the demographic pressure and desertification is the decline in land available for cultivation, leading to a decline in the number and length of fallows. The short-run result is that soils are unable to rebuild their nutrient base to the level required to sustain even current levels of production. This exposes Sahelian farmers to a high probability of declining yields over time.

Poorly Developed Infrastructure. The Sahel is one of the most poorly endowed regions of Sub-Saharan Africa with respect to infrastructure -- roads, health services, education, etc. All of these insufficiencies contribute to low agricultural productivity and food supplies that fail to meet growing demand. Deficits become even more dramatic during years of poor harvests.

In designing an SG 2000 program for the Sahel, these diverse conditions and farmers' responses to them are being taken into account.

3.1.2. The Principal Risks

> In semiarid regions, farmers are, on the average, strongly averse to risk. They often have few farm resources or ready access to credit. Their environment is also unpredictable. Yields vary substantially with the low and highly variable rainfall. Insect and disease pests also can substantially affect yields. Prices fluctuate with the large weather-related changes in supply and the inelastic demand. Fortunately, prices often move in the opposite direction to yields, thereby reducing income variability (Sanders, Shapiro, and Ramaswamy 1996, p.135).

Risk, as noted above, is an ever-present aspect of agricultural activities in the Sahel. Agroecological risk factors are among the most important, as they directly affect yields and aggregate production.

Production risk. Numerous factors contribute to inter-annual variability in food production. For the Sahel, it is generally the risk of poor rains that gets most of the attention, and not without just reason, given the serious droughts of the past and the extremely variable levels of effective rainfall (Goze 1990). For example, about 60% of the inter-annual variability of Malian millet and sorghum yields has been attributed to rainfall (Lecaillon and Morisson 1987, p. 30).

Price and Income Risk. Price instability for agricultural products in SSA tends to be much greater than elsewhere (Hugon et al. 1995, Nubukpo 1999). For example, the coefficient of variation for maize prices in SSA is about 30%, while it is only 11% for the rest of the world

[2]We use the term "desertification" in the same sense as it is used in the UN Convention to Combat Desertification, namely substantial soil degradation, and not in the popular sense of the inexorable creep of the Sahara Desert southward.

(Requiers-Desjardins 1995, p.226). This exceptionally high variability has macroeconomic implications, as farmers tend to produce less marketable surplus than they would in a less volatile price situation (Just and Zilberman 1986).

Institutional Risks. Institutional risks are those emanating from legislation affecting the agricultural sector, particularly legislation affecting how well input and output markets function. Farmers' capacity to meet the commercial demand for agricultural products depends largely on agroecological conditions, the institutional environment, and the type of technologies available (Dioné 1989, p.8). It is important to recognize that institutional risks are equally as important as agroecological and technological factors in affecting production decisions. Unfortunately, the institutional environment in most Sahelian countries is characterized by high levels of risk due, in large part, to short-sighted policy analysis and decision making. This results in inefficiencies in input and output markets. Despite efforts to liberalize markets in SSA, the presence of multiple, often contradictory, objectives among the various actors continues to create challenges. Furthermore, government commitment to liberalization has varied across the continent, leading to incomplete implementation of prescribed programs and spotty results in many cases.

In any case, the multiple risks that confront Sahelian farmers represent serious development constraints. They contribute to an attitude of risk aversion that results in very conservative decisions on the part of producers. These constraints are taken into account by SG 2000 as it attempts to adapt its program to the particularities of the Sahelian environment while remaining loyal to the underlying principles of the more general SG 2000 approach to technology adoption in West Africa described earlier.

3. 2. Meeting the West African Challenge: SG 2000's Sahelian Activities

SG 2000 began working in the Sahel in 1996 with the establishment of programs in Burkina Faso and Mali. Three seasons of activities in both countries have given SG 2000 the opportunity to begin adapting its general extension strategies to the particular conditions that characterize the Sahel. Although the Burkina and Malian programs are similar in many respects, there are some differences. This section of the paper draws primarily from the Malian experience, but mentions some of the activities in Burkina Faso to illustrate particular points that are not easily illustrated with Malian examples.

During the last three years, SG 2000 has pursued two principal technology approaches in the Sahel: one focusing on irrigated production (Office du Niger, Sélingué, and Baguineda in Mali and Sourou in Burkina Faso) and the other on rainfed crops.

For the irrigated systems, control over water availability -- though not perfect -- substantially reduces the production risk faced by farmers. The high-potential irrigated crops in both countries are rice, maize, and some horticultural products (onions and tomatoes, in particular). These crops already provide high yields: more than 5 tons/ha for rice in the Office du Niger (with potential to 8 or 9 tons) and also about 5 tons for high-protein maize varieties such as Obatanpa grown in the Baguineda area. These high yields are attributable to the water control as well as the relatively high levels of external inputs (improved seed, fertilizer, pesticides) used under irrigated conditions.

Although SG 2000 is working with farmers to improve yields in the irrigated areas, the greater challenge in the Sahel is in the rainfed cereal production zones such as the Mossi Plateau of Burkina Faso or the Dogon Country of Mali. These are zones where cereal crops -- primarily millet, sorghum, and fonio -- must constantly battle against both biological and non-biological constraints. The winning trio of the Green Revolution -- improved seeds, irrigation, and chemical products such as fertilizers and pesticides -- are put to a rigorous test under these Sahelian conditions. In addition to problems of insufficient or poorly distributed rainfall, there are major problems related to seed selection and protection and soil quality.

Improved varieties of millet and sorghum are used on less than 5% of the area cultivated. Mildew and striga (a parasitic weed) are among the most vexing and destructive of the diseases and parasites that afflict Sahelian crops. Mildew has been credited for losses of up to 61% of production (Singh et al. 1993) and striga, whose incidence increases as soil quality declines, is capable of completely destroying a field of millet. Despite the damage that can be inflicted by plant diseases and parasites such as mildew and striga, the potential solution to most of the Sahel's agricultural production problems appears to lie first and foremost in efforts to improve soil quality.

Indicators of soil quality suggest a crisis situation. Population pressure on the land has resulted in declining length and frequency of fallow periods previously used to renew soil quality. Farmers have limited scope to increase production through extensification because new land is increasingly difficult to find and generally of marginal quality. Consequently, they are now mining their soils in an effort to meet growing food and fiber needs. Soils are becoming increasingly deficient in nutrients. Smaling (1993) estimates that Mali has moderate depletion rates by SSA standards (>10 kg/ha/year of N, >4 kg of P, and >10 kg of K) and Burkina Faso has high rates (>20 kg/ha/yr of N, >8 kg of P, and >20 kg of K). Furthermore, declining levels of organic matter in these countries are frequently linked to increasing soil acidity and problems of aluminum toxicity. There is concern that organic matter may reach such low levels that it will be impossible to bring some soils back again to productive status.

Improving soil quality involves not only use of external sources of nutrients (organic and inorganic fertilizers) as commonly recommended by SG 2000, but also finding ways of reducing nutrient costs, improving the efficiency with which they are used, and reducing erosion. Attempts to reduce costs have led to work on rock phosphates and organic sources of nitrogen. Research trials have shown that although rock phosphates from Tilemsi in Mali (PNT) and Burkina (BKP) are slow to dissolve and become available to plants, over a period of several years they can increase soil nutrient content and yields while frequently improving soil PH (Bationo et al. 1998). Another approach recommended for reducing nutrient costs is the integration of agro-forestry techniques and/or rotations and intercropping with nitrogen-fixing leguminous crops. The most common set of recommendations for increasing nutrient efficiency and/or reducing erosion in the Sahel concerns the use of management practices that diminish wind and water erosion, increase soil organic matter, soil texture, and moisture holding capacity. Among the accompanying practices now being recommended by researchers and extension programs throughout the Sahel are compost pits (often supplemented with rock phosphates), anti-erosion dikes, stone retaining walls, and hedge fences to protect against wind erosion[3].

Although SG 2000 programs in SSA are frequently thought of as strictly high-external input programs promoting primarily improved seeds and chemical fertilizers, the Sahelian programs now underway are working with some of the cost-reducing, efficiency-augmenting techniques listed above.

3.2.1 SG 2000 Activities Now Underway in Three Regions of Mali

The SG 2000 program in Mali now operates in the zones of Koulikoro, Mopti, and Ségou, offering a variety of technical packages for millet and sorghum under rainfed conditions, maize under both irrigated and rainfed conditions, and rice under irrigated conditions (Table 3). The number of program participants increased from 411 to 1413 from 1996 to 1998, with the coverage of villages increasing from 36 to 85 during the same period.

Table 3. SG 2000 Technology Options Offered in Mali, by Zone and Crop System

Crop system→ Zone↓	Rainfed	Irrigated	Pure Stand	Mixed crop
Ségou	intensive millet millet + Apron intensive sorghum	intensive, high-protein maize	intensive millet millet + Apron	
Mopti	intensive millet intensive sorghum		intensive millet intensive sorghum	millet with cowpeas
Koulikoro	millet variety tests, intensive maize intensive sorghum	intensive rice intensive, high-protein maize	intensive millet, intensive, high-protein maize intensive sorghum intensive rice	

As in the programs already described for Benin and Ghana, the key extension instrument is the half-hectare "PTP" (production test plot). This is a half hectare of a participant farmer's land

[3] Gakou et al. 1995 note that in areas where it is a serious problem, wind and water erosion are capable of displacing topsoil at a rate of 3 t/ha each year.

cultivated by the farmer using one of the production packages recommended by SG 2000. Land permitting, the farmer is also asked to cultivate a control plot (CP) -- an additional half hectare of land planted with the same crop but using the production practices that the farmer would normally use. In the view of SG 2000, cultivation of both the PTP and the CP provides the best possible means of showing the farmer the differences between current and recommended practices with respect to both yields and income potential. Usually, organic matter (animal manure or compost) is applied to both the PTP and the CP; but inputs such as inorganic fertilizers, improved seeds, and pesticides are applied to only the PTP.

One of the interesting aspects of the SG 2000 Sahelian program is the attempt to develop incremental steps so that farmers can gradually move from current practices to input-intensive practices, thereby improving their skills and financial capacity to work with new technologies year by year. The millet program in Mali is illustrative. The intent is to provide farmers with options for three levels of intensification representing increasing costs, risks, and yields:

a. improved seed and mildew protection,
b. package ‘a’ plus light/low-cost fertilization,
c. package ‘a’ plus heavy/higher-cost fertilization.

In zones of high millet production risk, one of the key constraints identified by farmers was mildew -- as noted above, more than 60% of a crop can be lost to this problem. With assistance from the Novartis company (developer of an anti-mildew seed treatment called Apron plus), SG 2000 offered farmers a low-cost technology package of improved seed plus an Apron treatment (total cost to the farmer per PTP of 4,100 FCFA).[4] Moving up to the second level, farmers continue use of the improved seed and Apron but add an ‘improved’ compost consisting of a normal compost (from 3 to 5 tons/ha) supplemented with rock phosphate (this option was being introduced in 1999, so results are not yet available). The third level -- for farmers having tried the first two levels as well as those willing/able to move directly to this level -- consists of improved seed, Apron, compost, 100 kg/ha of natural phosphate (PNT), and 100 kg/ha of NPK.[5]

The sorghum, maize, and rice technologies offered thus far begin at a more intensive level, with use of improved seed, seed treatment (thioral) for sorghum, and inorganic fertilizers.

Although the quantitative results obtained by comparing the PTP and CP for the various technologies are not yet statistically robust due to the small numbers of observations per village/zone, they provide preliminary evidence that some of the PTPs may be outperforming the CPs. Table 4 summarizes results for some pure stand plots cultivated by farmers in Koulikoro using intensive millet techniques: improved seed (with varieties differing by zone), fertilizer,

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[4] The farmers’ cost of the package is primarily the cost of the seed, as Novartis has been donating the Apron thus far.

[5] The NPK was a formula introduced to Mali in collaboration with Hydrochem-Cote d’Ivoire. It is a bulk blended NPK (23-13-13) with S/MgO/Zn.

and Apron treatments. Overall averages reported at the bottom of Table 4 indicate that the PTP yields were 77% greater than the CP yields; taking into account only the 4 villages for which there was a CP yield recorded, however, the average PTP yield of 1250 was 84% greater than the average CP yield. These good results are due, in part, to the excellent 1998 rains, which were adequate in quantity (797 mm) and in distribution (spread over 54 days).[6]

Table 4. Yield Results for Intensive Millet and Control Plots in Koulikoro, 1998

Villages	Number of cases	Millet Variety	Yields (kg/ha) PTP	Yields (kg/ha) CP*
Sébénicoro	7	Guefoue	1440	768
Djenidié B	15	Benkadinio	1378	775
Samakélé	9	Benkadinio	1343	n.a.
Hababougou	9	Toroniou	1347	n.a.
N'Tjibougou	1	Toroniou	1046	n.a.
Tiécourala	1	Toroniou	960	n.a.
Seribougou	3	Toroniou	931	500
Average	45	Mixed	1206	681

Source : Galiba et al. 1999, p.9.
* CP were planted using local varieties, no Apron, and no inorganic fertilizer.

Table 5 summarizes results for the lowest-cost millet technology described above (improved seed and Apron). One notes a strong reduction in the incidence of mildew (from 39 to 9%) but a less strong improvement in yields (from 810 kg/ha to 911 kg/ha).[7] In addition to these preliminary plot results, there is evidence from research trials that the use of Apron plus can increase yields by as much as 30%. Furthermore, studies conducted by the Cinzana research center indicate that 70% of farmers in that zone had adopted this anti-mildew seed treatment (SRA, Cinzana 1993).

[6] These rainfall figures are better than those for 1997: 730 mm over only 44 days.

[7] The averages for table 5 are weighted by the number of observations in each zone.

Table 5. Results of Mildew Treatment Package for Millet: Ségou, 1998

		PTP		CP		
Zones	Number of Cases	Mildew Incidence (%)	Yield (kg /ha)	Mildew Incidenc e (%)	Yield (kg /ha)	Percent Increase in Yield
Dioro	62	5	1270	25	1204	5
Baroueli	41	7	1104	33	899	23
Cinzana	180	10	794	48	707	12
Ségou	68	11	778	29	618	26
Average*		9	911	39	810	12

Source :Galiba et al. 1999, p.6.
* Average is weighted by the number of observations for each case.

Table 6 presents preliminary results from tests of millet performance when cultivated in association with cowpeas. The number of observations is quite small, making it difficult to generalize. For the 17 cases where an improved variety was used, the average PTP yield exceeded the average CP yield by 20 to 40%, depending on zone. For the 27 cases where local seed was used, the results were mixed, with the CP outperforming the PTP in 12 cases and the PTP outperforming the CP yield by 38 or 45% in the other 15 cases, depending on the zone. Table 7 presents a very rough estimate of financial returns to selected millet and sorghum packages using 1998 yield results and prices.[8] Although these partial budget results are very rough estimates based on a limited number of PTP/CP yield comparisons, they do suggest that farmers would be more likely to adopt the millet/Apron package, which has a marginal rate of return over 200%, than the other three packages, whose marginal rates of return do not even reach 30%. Despite average yields of 1.5 tons/ha for sorghum and 1.2 tons/ha for millet during the relatively good rainfall of 1998, the costs of the intensive packages are so high that the marginal rates of return are only 17 and 3%, respectively. Even with the addition of cowpeas -- a higher valued crop than millet and sorghum -- to the cropping system, the marginal rate of return rises to only 28%. These results help to explain why many farmers in the Sahel are still reluctant to purchase inorganic fertilizers: not only is there a high risk of poor weather that could adversely affect fertilizer response and yields, but financial returns do not provide strong incentives even when the weather is good.

[8] The SG 2000 price for the millet/sorghum intensification packages was 43,400 FCFA/ha and was 4,100 FCFA/ha for the millet/Apron package. Typical producer prices faced by farmers in the SG 2000 zones during 1998 are estimated to have been 80 FCFA/kg for millet and sorghum and 150 FCFA/kg for cowpeas.

Table 6 : Results for Millet Grown in Association with Cowpeas: Mopti, 1998

Villages	Number of Cases	Variety	Yields in kg/ha PTP	Yields in kg/ha CP
Dangaténé	10	IBV 8001	911	750
Toroli	7	IBV 8001	399	163
Kona	10	Local	880	602
Koumé	12	Local	758	890
Koko	5	Local	548	396

Source : Galiba et al. 1999, p.6.

Table 7. Partial Budget Results for Recommended Millet and Sorghum Packages

Package	Production Test Plot: Variable costs	Production Test Plot: Gross revenue	Control Plot: Gross revenue	Production Test Plot: Marginal net benefit	Production Test Plot: Marginal rate of return
	(CFA Francs per hectare)				(%)
Intensive Millet	40800	96480	54480	1200	3
Intensive Sorghum	39950	116720	69920	6850	17
Millet/cowpea	43400	105720	50320	12000	28
Millet + Apron	4100	78800	64960	9740	237

Source: Galiba et al. 1999, p. 7.

These preliminary results underline the importance of developing a better understanding of the factors that influence farmers' adoption behavior. Why are some farmers willing to accept the risk associated with the more intensive packages, despite the relatively low financial returns, while others are not? Why do some hesitate to try the millet/Apron package despite the strong financial returns and much lower risk? What role do risk perceptions and attitudes play in the choice of technology versus knowledge of the technology and ability to use it correctly? What can be done to improve adoption of highly profitable technologies and the targeting of more risky ones to those who can best bare the risk?

These are the types of questions now being asked by SG 2000 and their collaborators as they attempt to expand their program evaluation beyond the more straight-forward issues of comparing average yields and agronomic potential for PTP and CP. There is a growing recognition that more attention must be given to evaluating the financial and economic consequences of technology adoption by SG 2000 participants. We have already noted earlier that despite their importance, agroecological factors are only one set of the many factors that must be taken into account if farmers are to intensify production in a sustainable manner that will lead to a successful agricultural transformation.

Socio-economic factors such as the compatibility of the proposed innovations with the village social structure, the financial profitability of the packages, and the availability of output markets, all need to be addressed in order to assure adoption. For example, new technologies can easily bring to the surface power conflicts because the technologies may lead to changes in relative income and social organization. Financial profitability depends not only on agronomic response but is also the existence of reliable markets for the output being produced. It is thus essential to move from a narrow agronomic view of intensification to a broader vision that includes the full range of agro-socio-economic factors that contribute to or constrain intensification.

The need to look at socio-economic aspects of the SG 2000 package is particularly important in the Sahelian environment, where potential yield levels may play a less important role in adoption decisions than yield variability. This raises the question of whether it is possible in the Sahel -- as it was in humid and sub-humid zones of West Africa -- to judge the potential success of intensification technologies simply by their capacity to increase yields. In other words, in an environment as risky as that existing in the Sahel, what should be the determinants of successful adoption of technologies designed to promote agricultural transformation? Furthermore, what should be the pertinent indicators to examine when evaluating whether a technology has been successfully introduced? These questions suggest a research program in two stages:

- the first step is to understand the factors that determine whether farmers participate in an intensification program such as that offered by SG 2000 (e.g., the agroclimatic environment, type of crop involved, quality of information made available, package costs, level of income, ...)

- the second step is to identify the conditions, beyond those identified above, that enable progress toward agricultural transformation.

We now turn to a discussion of the steps necessary to accomplish the first stage of this research.

3.3. Elaboration of Hypotheses Concerning the Determinants of Production Behavior Exhibited by Participants in the SG 2000 Program in Mali

A questionnaire addressing the following questions has been developed and is currently being administered to a group of farmers:

a) *What are the factors that determine whether a farmer adopts an SG 2000 technology package (or, at a minimum, what determines a farmer's participation in the SG 2000 program)?*

For the present purposes, adoption is defined as the act of accepting to use an SG 2000 package on a PTP (i.e., the act of participating in the SG 2000 program for the first time). As the research program progresses, the study will try to measure not only initial participation but also: (i) continued participation and (ii) the degree of participation (measured by the percent of particular packages actually used and level of external inputs involved).

b) *What are the financial consequences of adoption for SG 2000 participants?*

In view of improving the preliminary analyses of profitability presented in Table 7, detailed input/output and cost data will be collected on a larger group of participants so that more complete crop budgets can be prepared to evaluate the absolute and relative profitability of the different packages being offered to SG 2000 farmers. The first step is to increase the number of PTP and PC for which reliable yield data are available in a given year. The second step is to control for various factors that might contribute to variability in yields across farms and zones (labor use, rainfall, pest attacks, etc.). The third step is to build a data series that covers several years, permitting better analysis of risk over time.

c) *How do farmers analyze available information about proposed technologies when deciding whether to adopt the package (or parts of it)?*

As noted above, agricultural production is a high-risk activity, particularly in the Sahel where yields and incomes vary from year to year. Farmers must process large amounts of information when making cropping decisions and develop expectations about yields and prices, among other things. What are farmers' perceptions of potential yields, expected prices and related risks? What do they do to minimize risks? What impact does the adoption of new technologies have on their perceptions and ability to manage risk?

d) *Following the collection of data related to questions 'a'- 'c', the following methods are proposed for analysis.*

- Logit and Probit regression models to estimate the relative importance of different determinants of adoption for which data are being collected.

- Improved financial analysis of new technologies, through the development of more detailed crop budgets.

- Development of a conceptual framework permitting better analysis of the degree of financial risk faced by farmers adopting the SG 2000 technologies, and the role that risk perceptions play in shaping adoption decisions.

After the above analyses have been accomplished, it will be possible to develop recommendations concerning actions likely to successfully stimulate agricultural intensification. To go beyond agricultural intensification to agricultural transformation will require a more thorough study of the entire subsector for each crop concerned. In particular, a study that takes into account how well input and output markets are functioning appears indispensable if Sahelian countries are to move toward a viable agricultural development policy.

4. CONCLUSIONS

The challenges associated with efforts to intensify agricultural production are always complex. In fact, West African farmers developed production patterns that have permitted them to live in harmony with their environment for many centuries. These production choices were based on rational decisions given the prevailing context, though a good understanding of these decision processes requires an excellent knowledge of the rural setting within which farmers operate.

Even with a well designed, rational decision making process, however, there is a gap between what farmers are producing and what consumers are demanding. This has created major macroeconomic problems in much of SSA. Intensification -- one of the pillars of agricultural transformation in West Africa -- is, therefore indispensable. Accomplishing this transformation is not an easy task. It presupposes the arrival of new technologies that can increase yields to a point where farmers are regularly producing marketable surpluses -- a prerequisite for ensuring food security in West Africa. Movement toward agricultural transformation also stimulates the hopes of the farming population for a better life and a higher income that will allow them to respond more rationally to market signals. Agricultural extension services, a key ingredient in any movement toward intensification, have often erred by trying to move too quickly in a milieu that is not accustomed to acting precipitously. The real challenge is in promoting an intensification that will continue through time rather than one that is short-lived. This requires that farmers internalize the methods being promoted rather than viewing them as externally imposed. The SG 2000 experience in the humid and sub-humid zones of West Africa suggests that their efforts were successful. But, as noted above, the Sahelian context is different and natural conditions less favorable. Success in the Sahel will require greater effort to combat the agroecological constraints and to take into account the socioeconomic factors that influence intensification strategies.

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